

**UNCLASSIFIED**

---

**AD 402 600**

*Reproduced  
by the*

**DEFENSE DOCUMENTATION CENTER**

**FOR**

**SCIENTIFIC AND TECHNICAL INFORMATION**

**CAMERON STATION, ALEXANDRIA, VIRGINIA**



---

**UNCLASSIFIED**

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

FTD-TT- 63-101

63-3-3

ASTIA  
402 600

# TRANSLATION

STUDYING THE HARDNESS OF TUNGSTEN AT TEMPERATURE  
RANGES OF FROM 20-2700°

By

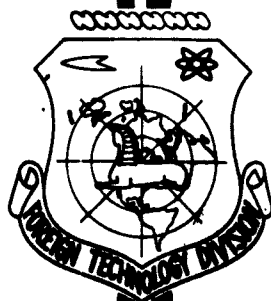
G. S. Pisarenko and V. O. Borisenko

## FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

WRIGHT-PATTERSON AIR FORCE BASE

OHIO



## UNEDITED ROUGH DRAFT TRANSLATION

STUDYING THE HARDNESS OF TUNGSTEN AT TEMPERATURE  
RANGES OF FROM 20-2700°

BY: G. S. Pisarenko and V. O. Borisenko

English Pages: 7

SOURCE: Ukrainian Periodical, Dopovidi Akademii Nauk  
Ukrains'koi RSR, Nr. 8, 1962, pp 1053-1056

S/21-62-0-8

THIS TRANSLATION IS A RENDITION OF THE ORIGINAL FOREIGN TEXT WITHOUT ANY ANALYTICAL OR EDITORIAL COMMENT. STATEMENTS OR THEORIES ADVOCATED OR IMPLIED ARE THOSE OF THE SOURCE AND DO NOT NECESSARILY REFLECT THE POSITION OR OPINION OF THE FOREIGN TECHNOLOGY DIVISION.

PREPARED BY:

TRANSLATION DIVISION  
FOREIGN TECHNOLOGY DIVISION  
WP-APB, ONR.

Studying the Hardness of Tungsten at Temperature  
Ranges of from 20-2700°

by

G. S. Pisarenko and V. O. Borisenko

1. The development of modern electric power machine construction and atomic energy actually depends upon providing same with the necessary materials, capable of resisting the effects of various types of power and thermal loads under conditions of high and ultrahigh temperatures. For these purposes are frequently used such high melting materials as tungsten, tantalum, molybdenum, niobium, their alloys and compounds whose physical-mechanical properties must be investigated in a wide range of temperatures of from 20 - 3000° and over.

To solve this problem it is necessary to make complex investigations, connected with the development of new methods and creation of suitable experimental installations, which allow a sharp rise in the existing temperature level of many kinds of high temperature mechanical tests.

In the strength department of the Ceramet. and special Alloy Inst. of the Academy of Sciences Ukr-SSR was developed a series of methods and original installations for complex investigation in an inert medium the power characteristics, plasticity, hardness and elasticity constant of a whole series (perspective and already used) materials in a wide range of temperatures from 20 to 3000° [1]



Fig. 1. Testing of samples by the method of unilateral flattening. 20-2700°.

In the given report are briefly described certain results of investigating the temperature/hardness dependence of the most high melting metal tungsten at temperatures of

2/. In view of the fact that the temperature level of hardness measurements until our experiments were carried out over that branch was 1650-1800°, we made it our task to investigate the hardness at temperatures of 2000-3000°, for which it was first of all necessary to develop a method and to construct a suitable installation.

With such a suitable method, thoroughly developed at the at the Energetic Department of the USSR of the Academy of Sciences Ukr-SSR came a method of unilateral flattening conical models (fig.1). This method [1] when applying the installation as proposed by us [2] enabled to raise the temperature level and to determine hardness at temperatures of up to 2700°.

The method offers the possibility of determining hardness in a medium of purified inert gases - argon or helium. At a temperature range of 20-1,50° hardness was measured by the method of static impression of a sapphire indenter of standard proper four corner pyramid with an angle between opposite edges of 136° (according to GOST 2999-59).

At temperatures of 1750-2700° hardness was determined by data of unilateral flattening of conical models with an angle at the top of 120° in accordance with formula

$$H_s = \frac{P}{F} = 1,2732 \frac{P}{d^2} \frac{\text{kg}}{\text{mm}^2} \quad (1)$$

where P- load on the sample, which is applied through punch, kg; F-area of the impression, which is formed on the sample after flattening, mm<sup>2</sup>; d- diameter of impression, mm.

When determining hardness by the method of static impressing of an indenter the used sample, which has the form of a cylinder with a diameter of 8 mm and 5-7 mm in height, and for testing by the method of unilateral flattening one of the flat surfaces of the mentioned cylinder was additionally cone processed with an angle at the top of 120°.

The loads applied to the sample to make the indentation, was equal to 1 kg, when determining hardness by the method of static impression, and 5 kg, by the method of unilateral flattening. Duration of load application to the specimen was 60 sec.

The method of investigating hardness by the unilateral flattening method offers

good agreement with results obtained by the method of static impression of the indenter [1].

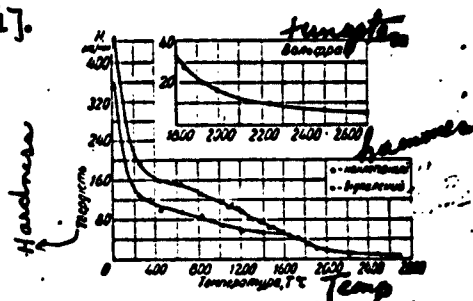


Fig. 2. Dependence graph of tungsten hardness upon temperature.

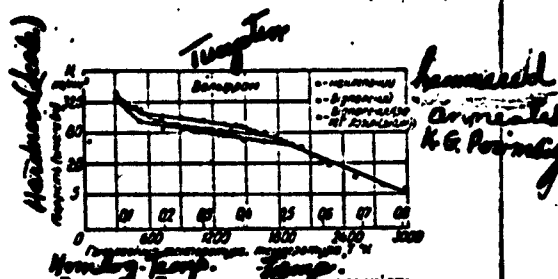


Fig. 3. Temperature dependence of tungsten hardness in semilogarithmic coordinates.

Given below are data of studying hardness of samples, made of forged tungsten wires type VRN, obtained by the powder metallurgy method of the Moscow Electric Lamp Plant.

The temperature of the sample in the range of 20-2000° was measured with the aid of thermocouples and controlled by an optical pyrometer. The temperature of the sample, punch and heater of over 2000° was measured only with the optical pyrometer, the indications of which were checked by the melting point of pure molybdenum.

To obtain hardness data by the method of unilateral flattening in the temperature range of 1750-2700° as punch material was used : zirconium carbide and an alloy of hafnium and tantalum carbides in ratio of 1:4<sup>1</sup>.

3. Hardness/temperature dependence data of deformed and annealed tungsten in the range of temperatures of 20-2700° are given in form of graphs in fig. 2. Hardness values of annealed tungsten were obtained when examining the samples during the quenching from a temperature of 1750° to room temperature.

The investigation results indicate that hardness of deformed as well as annealed tungsten drops sharply with the rise in temperature from 20 to 300°. At a further rise in temperature to 1600° hardness changes gradually, whereby the difference in hardness of deformed and annealed metal changes only slightly.

At a temperature of 1100-1200°, which according to the A.A. Bochvar law corres-

1. High melting compounds were obtained at the USSR of the Academy of Sciences USSR by V.M. Paderno under the supervision of member corresp. of Academy of Sciences G.V. Samsonov.

ponds to a recrystallization temperature ( $T_{\text{beg. of recryst.}} = (0.3 - 0.4) T_{\text{melt}}^{\circ\text{K}}$  [3]) the difference in hardness of deformed and annealed tungsten decreases rapidly. At 1600° recrystallization of the sample ceases and the curves fuse together at a hardness value of 51 kg/mm<sup>2</sup>.

At a rise in temperature to 1750°, which constitutes 0.55  $T_{\text{melt}}^{\circ\text{K}}$  the hardness decline begins, which is connected with the change in the mechanism of deformation, after which the hardness declined smoothly and reaches a value of 17 kg/mm<sup>2</sup> at 2000°, 7.3 kg/mm<sup>2</sup> at 2500° and 6 kg/mm<sup>2</sup> at 2700°.

4. The temperature/hardness dependence of pure metal (which has no allotropic conversions and does not age in connection with the presence of admixtures) is well described by the Ito-Shishokhin expression [4,5]

$$H = Ae^{-aT}, \quad (2)$$

where  $T$  - temperature in °K,  $A$  - hardness values, extrapolated in 0°K,  $a$  - thermal coefficient of hardness.

By logarithming expression (2) we obtain a dependence

$$\ln H = \ln A - aT, \quad (3)$$

which appears to be a straight line equation. When plotting data of temperature/hardness dependence in coordinates  $\ln H - T^{\circ\text{K}}$  the characteristic features of the dependence are better expressed.

We will present in semilogarithmic coordinates the data obtained by us for hardness of deformed and annealed tungsten, as well as the data by M.G. Lozinskiy [6] for annealed technically pure tungsten, also obtained by the powder metallurgy method (fig.3).

Analysis of data obtained by this method allows to draw a conclusion, that the temperature/hardness dependence of deformed and annealed tungsten during the plotting in semilogarithmic coordinates is well represented by a broken curve, which consists of three rectilinear sections with characteristic breaks in low temperature and high temperature zones. In this way, the dependence is subject to the exponential law (2) and has three sections with two constants  $A$  and  $a$  for each.

The break in temperature/hardness dependence was observed for a great number of pure metals - low temperature close to 0.1-0.15 [5] and high temperature close to 0.5-0.55 [4,5] of homologous temperature scale.

To compare the dependence of hardness changes on temperature with other power characteristics in fig.4 is shown the temperature dependence of power boundary of deformed tungsten.

When examining the dependence, shown in fig.4, it becomes evident, that the temperature dependence of the power boundary<sup>1</sup> of tungsten is subject to exponential law and is well described by the Frantsevich-Bratskiy expression [7]

$$\sigma_p = B e^{-\frac{Q}{RT}}, \quad (4)$$

where T - temperature in °K, B-values of power boundary, extrapolated by 0°K;  $\beta$ -thermal coefficient of power boundary.

Just as for many pure metals the power boundaries (fig.4) are well revealed only by the high temperature break close to 0.5  $T_{\text{melt}}$  °K. There are insufficient data to determine the point of low temperature break, but from report [5] is evident, that such a break does exist for tungsten elongation at a homologous temperature of the order of 0.15

Both high- and lowtemperature breaks in curves, which express temperature/hardness dependence and power boundaries, are connected with the change in the mechanism of deformation, but the true mechanism of these changes is still not completely explained. [4,5]. The change in mechanism of plastic deformation and its role in the formation of mechanical properties have been thoroughly investigated by Ye.S.Yakovleva using pure aluminum [8].

In ratio to the temperature rise there is gradual change (in one after the other) in three basic deformation mechanisms. The changes in plastic deformation mechanism

1. Data of power boundary were obtained at the IASS of the Academy of Sciences USSR by V.K.Kuz'menko on species of tungsten investigated by us.

result in the appearance in low-temperature and high temperature breaks in temperature/hardness dependence curves and power boundary, plotted in semilogarithmic coordinates.

#### Literature

1. Collection "Problems of High Temperature Strength in Machine Construction" edited by G.S. Pisarenko, ITI, K., 1961. 2- V.A. Borisenko, G.S. Pisarenko; Powder Metallurgy 5, 95 (1961). 3- A.A. Bochvar; Metallography, Metallurgizdat, 1956. 4- J.H. Westbrook, Trans. ASM, 45, 221 (1953). 5- E.R. Petty, J. Inst. Metals, 89, 4, 123 (1960); 6- M.G. Lozinskiy; High Temperature Metallography, Mashgiz, 1956; 7- M. Vratskiy, I. Frantsevich STAL' 7-8, 74 (1932); 8- E.S. Yakovleva; Physics of Metals and Metallography 4, 141, 306 (1957)

Ceramer and Special Metals Inst.  
at the Academy of Sciences Ukr-SSR

Submitted: March 10, 1962

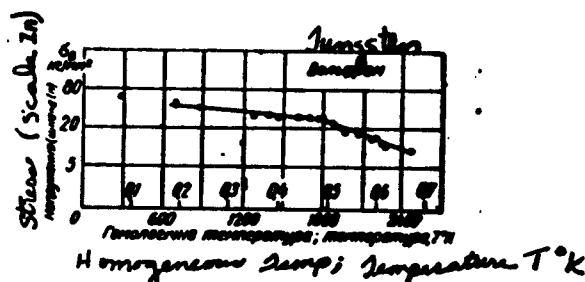


Fig. 4. Temperature dependence of Tugstven Strength

boundary.

# DISTRIBUTION LIST

DEPARTMENT OF DEFENSE	Nr. Copies	MAJOR AIR COMMANDS	Nr. Copies
		AFSC	
		SCFDD	1
		DDC	25
HEADQUARTERS USAF		TDBTL	5
		TDBDP	5
AFCIN-3D2	1	AEDC (AEY)	1
ARL (ARB)	1	ASD (ASYIM)	1
OTHER AGENCIES			
CIA	1		
NSA	6		
DIA	9		
AID	2		
OTS	2		
AEC	2		
PWS	1		
NASA	1		
ARMY (FSTC)	3		
NAVY	3		
NAFEC	1		
RAND	1		